USE OF TRUEGRO EXPANDED SHALE IN A LANDSCAPE MIX

Primary Investigators

John Sloan, Ph.D.
Assistant Professor
Environmental Soil Science

Steve George, Ph.D.
Associate Professor
Landscape Horticulture

Wayne Mackay, Ph.D.
Associate Professor
Environmental Horticulture

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EXECUTIVE SUMMARY

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Primary Investigators: Dr. John Sloan, Steve George, Wayne Mackay

RATIONALE: Urban landscape mixes are traditionally based on the organic ingredients, pine bark and peat moss. Although organic amendments are beneficial to soils, the length of their effectiveness is limited to the decomposition time of the organic matter. The addition of inorganic ingredients to the mix may increase the length of their effectiveness in soils. TrueGro expanded is a porous material that is able to absorb water and nutrients. It can improve plant growth when added to clay soils with poor porosity. This study was conducted to determine if inclusion of TrueGro expanded shale in landscape mixes would improve their performance. In addition to the traditional pine bark plus peat moss mix, we investigated the use of alternative organic ingredients, including municipal yard wasted compost, biosolids, and cottonseed hulls.

OBJECTIVES:
1. Determine the effect of expanded shale on plant growth in various landscape mixes.
2. Evaluate non-traditional organic materials as potential ingredients in landscape mixes.

METHODOLOGY: Four basic landscape mixes were prepared using traditional and alternative organic materials. The four mixtures were: 1) 75% pine bark + 25% sphagnum peat moss, 2) 50% pine bark + 50% wastewater biosolids, 3) 100% municipal yard waste compost, and 4) 65% pine bark + 35% cottonseed hulls. TrueGro expanded shale was blended with each of these mixtures at rates of 0, 15, 30, and 60%. In total, 16 landscape mixes evaluated (i.e., 4 organic blends x 4 TrueGro expanded shale rates). Physical properties of the mixes were measured to determine how they compared to traditional greenhouse growing media. Each landscape mix was transferred to 3 sets of greenhouse pots. The annual flower, Vinca *(Catharanthus roseus)*, was directly seeded into one set of pots, clippings of the perennial flower Verbena *(Verbena hybrida)* were transplanted into the second set, and Shantung Maples seedlings *(Acer truncatum)* were transplanted into the third set. Plant growth was monitored to determine how each landscape mix affected plant growth and development. Vinca and Verbena plants were harvested to determine total biomass yield. Vinca plant tissue was chemically analyzed to assess how the landscape mixes affected nutrient and heavy metal uptake.

RESULTS: Expanded shale increased the bulk density of all landscape mixes. The effects on total porosity and container water capacity were mixed. Expanded shale decreases the total porosity and container water capacity of the 75% pine bark + 25% sphagnum peat moss mix and the 65% pine bark + 35% cottonseed hulls mix, but increased these same properties in the 50% pine bark + 50% wastewater biosolids mix and the 100% compost mix. Plant performance was affected by the basic organic ingredients in each landscape mix as well as the amount of TrueGro expanded shale. The annual flower, Vinca, grew best in the compost mixture and its performance was improved by blending up to 30% expanded shale into the mixture. Both the perennial flower, Verbena, and the woody ornamental, Shantung Maple, grew best in the 50% pine bark + 50% biosolids mixture, followed closely by the 75% pine bark + 25% sphagnum peat moss mix and the 100% compost mix. For all three species evaluated, plant growth in the 100% compost mix was improved by the addition of 15 and 30% expanded shale, but plant growth in the 75% pine bark + 25% sphagnum peat moss mix and the 50% pine bark + 50% biosolids mix was diminished by including expanded shale in the mix. Expanded shale increased the uptake Ca and Mg by Vinca, but decreased the uptake of phosphorus. Decreased P uptake was probably due to P adsorption. Expanded shale decreased the plant uptake of some trace metals, probably by increasing pH of the landscape mix and decreasing metal solubility.

CONCLUSION: It is possible to develop functional landscape mixes that include non-traditional organic ingredients plus up to 30% expanded shale. TrueGro expanded shale will improve the performance of landscape mixes that primarily contain decomposed or composted organic materials. The increased performance is probably due to an improvement in the physical properties of these mixtures – particularly porosity and water holding capacity.

USE OF EXPANDED SHALES IN A LANDSCAPE MIX

INTRODUCTION

Landscape mixes are commonly used in urban settings around horticultural plantings. Pine bark and peat moss have traditionally been the major ingredients of these mixes. Because these materials are organic[1], the length of their effectiveness is limited by eventual decomposition. Also, short-term nitrogen deficiencies are sometimes caused by the addition of these materials to soil due to a high carbon to nitrogen ratio. Clay textured soils would benefit from amendments that supply essential plant nutrients and also permanently improve soil texture and structure.

Earlier research showed that the porous nature of expanded shale allows it to absorb moisture and soluble nutrients and later release those nutrients to plants. This property could make expanded shale a beneficial ingredient of landscape mixes, especially when combined with decomposable organic materials such as compost and biosolids. Expanded shale may adsorb nutrients released from mineralized organic matter and extend the time they are retained in the plant rooting zone.

OBJECTIVES

1. Determine the effect of expanded shale on plant growth in various landscape mixes.
2. Evaluate non-traditional organic materials as potential ingredients in landscape mixes.

MATERIALS AND METHODS

Overview: This study evaluated the effect of expanded shale on a traditional landscape mix and several alternative mixes. Organic materials used in the mixes are listed in Table 1 along with their total nitrogen and carbon contents. The traditional landscape mix contained peat moss and composted pine bark. The alternative mixes used non-traditional materials, including compost, biosolids, and cottonseed hulls. Physical and chemical properties of the various mixtures were measured in the laboratory, followed by a greenhouse evaluation of the mixes as a growing medium for annual, perennial, and woody ornamental plants.

Mixes: Each ingredient was mixed in the form it was received without additional processing. Mixing ratios were based on volume. Organic ingredients were first mixed to create four basic landscape blends (Table 2). Then, expanded shale (TXI TrueGro) was added to the basic organic mixes at rates of 0, 15, 30, and 60% to create the 16 blends shown in Table 3.

Table 1. Total carbon and nitrogen content of basic organic ingredients used in landscape mixes.

Landscape Mix Ingredient	Total N	Organic Matter	C:N
	(g/kg)	(g/kg)	
Aged Pine bark (PB)	3.2	945	293
Sphagnum peat moss (PM)	6.9	981	143
Compost	6.9	244	35
Biosolids (BS)	19.3	411	21
Cotton seed hulls (CH)	4.4	979	222

[1] The word "organic" is used in a pure sense to identify carbon-based materials originally derived from plants.

Table 2. Type and ratios of organic ingredients in each landscape mix. Soluble NO_3-N contents of each mix are shown in the last column.

Blend	Organic Ingredient 1	Organic Ingredient 2	Blend Code	NO_3-N (mg/kg)
1.	75% Pine Bark (PB)	25% Peat Moss (PM)	75-PB/25-PM	6.3 (0.9)†
2.	50% Pine Bark	50% Biosolids (BS)	50-PB/50-BS	395 (30)
3.	100% Composted Municipal Yard Waste		Compost	78.0 (11.4)
4.	65% Pine Bark	35% Cottonseed Hulls (CH)	65-PB/35-CH	11.5 (5.1)

† Standard deviation of the mean (N=4)

Table 3. Combinations of organic blends with TrueGro expanded shale.

Landscape Mix	Base Blend	TrueGro Expanded Shale Content
		(%)
1	75-PB/25-PM	0
2	75-PB/25-PM	15
3	75-PB/25-PM	30
4	75-PB/25-PM	60
5	50-PB/50-BS	0
6	50-PB/50-BS	15
7	50-PB/50-BS	30
8	50-PB/50-BS	60
9	100-Compost	0
10	100-Compost	15
11	100-Compost	30
12	100-Compost	60
13	65-PB/35-CH	0
14	65-PB/35-CH	15
15	65-PB/35-CH	30
16	65-PB/35-CH	60

Procedure: Ingredients were mixed in a portable cement mixer and then transferred to three sets of greenhouse pots. The size of the containers depended on the species to be grown. One set of pots was direct seeded with the annual flower, Vinca *(Catharanthus roseus)*. The second set was planted with rooted cuttings from the perennial flower, Verbena *(Verbena hybrida)*. The third set was planted with 1-year old seedlings of Shantung Maple *(Acer truncatum)*. This selection of plants encompasses those that might be selected by homeowners and other users of landscape mixes. A full label rate of Osmocote (14-14-14) was applied to all pots shortly after planting to promote the establishment of plants. However,

fertility levels were allowed to decline throughout the study so that the inherent nutrient-supplying capacity of each mixture could be evaluated. All pots received adequate watering throughout the study.

Plants were grown until maturity or for a sufficient period of time to determine positive and/or negative effects of the landscape mixtures on plant growth. As plants grew, they were monitored for overall plant performance using such characteristics as plant height and width, amount and color of foliage, and number of flowers. At the end of the study, aboveground dry matter yield was measured for the Vinca and Verbena flowers. Aboveground Vinca tissue was analyzed for total macro- and micro-nutrient content.

RESULTS AND DISCUSSION

Physical Properties

Bulk Density: Bulk densities of the basic landscape mixes (i.e., no expanded shale) were 0.24 g/cm^3 for the 75-PB/25-PM blend, 0.48 g/cm^3 for the 50-PB/50-BS blend, 0.68 g/cm^3 for the compost, and 0.21 g/cm^3 for the 65-PB/35-CH blend (Fig. 1). Adding expanded shale to the organic landscape blends

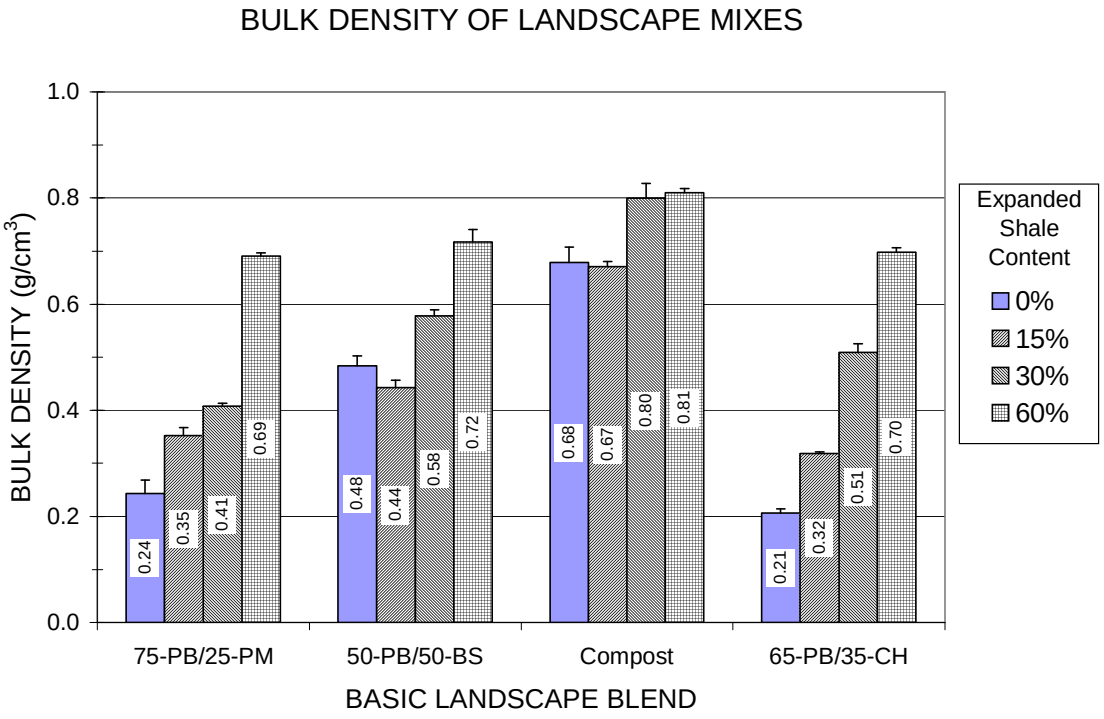

Fig. 1. Effect of TrueGro expanded shale on bulk densities of various organic landscape mixes.

increased their bulk densities. The biggest increases occurred with the low bulk density blends (75-PB/25-PM and 65-PB/35-CH) and smaller increases were observed for the higher density blends (50-PB/50-BS and compost). At the 60% rate of expanded shale, bulk densities were similar (0.69 to 0.81 g/cm^3) for all the landscape blends and were determined primarily by the bulk density of expanded shale itself. For comparison purposes, most retail potting mixes have bulk densities in the range of 0.1 to 0.4 g/cm^3. Adding expanded shale to the basic organic landscape blends increased their bulk densities to

levels that were less than optimum for direct potting of plants. However, higher bulk densities are not a problem when the mixtures are incorporated into soil.

Total Porosity: Total porosity is the volume of landscape mix that is occupied by air when the mix is completely dry. Total porosities for the basic landscape mixes (i.e., no expanded shale) were 75% for the 75-PB/25-PM blend, 58% for the 50-PB/50-BS blend, 41% for the compost, and 85% for the 65-PB/35-CH blend (Fig. 2). Blends with high porosities corresponded to those with low bulk densities. Expanded shale had no effect or slightly decreased the porosity of landscape blends that had high initial porosities (75-PB/25-PM and 65-PB/35-CH), but increased the porosity of blends that had low initial total porosities (50-PB/50-BS and compost). Expanded shale had the largest effect on compost. Without expanded shale, the total porosity of compost (41%) was lower than a typical mineral soil (50%). Adding expanded shale to the compost increased its total porosity to a more optimal level (57 to 68%). At the 60% rate of expanded shale, all landscape mixes had similar total porosities of around 70%.

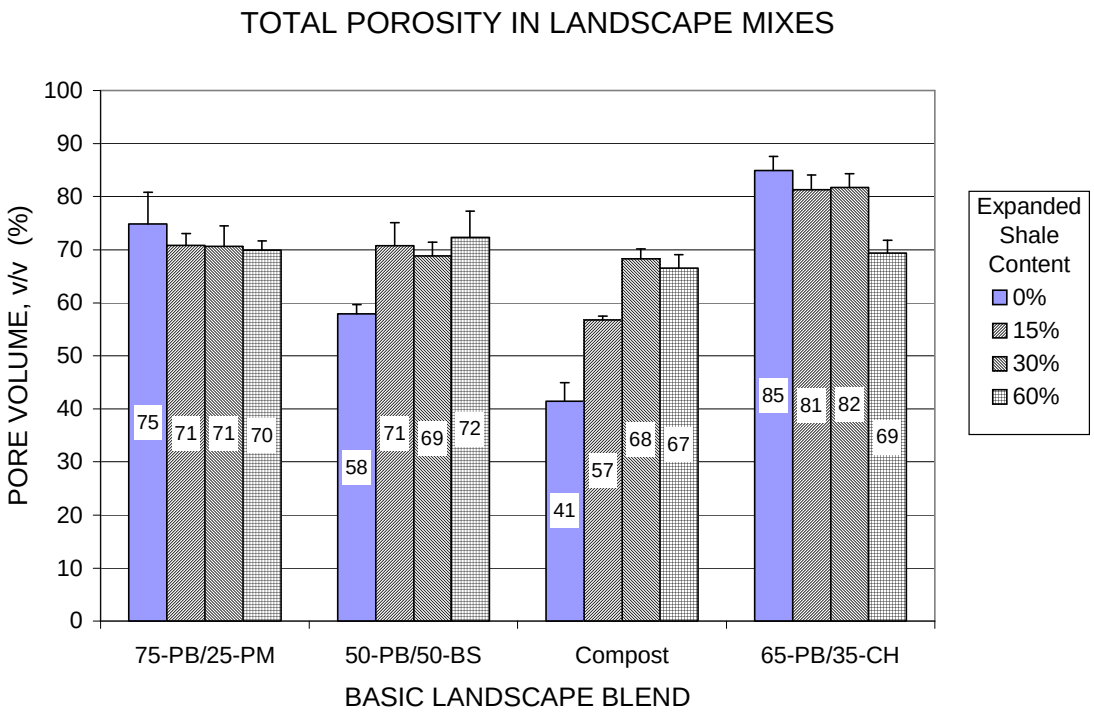

Fig. 2. Effect of TrueGro expanded shale on total porosity of various organic landscape mixes.

Container Capacity Water Content: When a growing media is placed in a greenhouse pot, saturated with water, and then allowed to drain, the amount of water left in the growing media after all excess water has freely drained is called the container capacity water content. It represents the greatest amount of plant available water the media can retain, and therefore, higher values are generally better. Container capacities for the basic landscape mixes (i.e., no expanded shale) were 59% for the 75-PB/25-PM blend, 35% for the 50-PB/50-BS blend, 22% for the compost, and 58% for the 65-PB/35-CH blend (Fig.3). For comparison purposes, the container water capacity of most retail potting mixes is in the range of 50 to 70%. Expanded shale greatly decreased the container capacity water contents of the 75-PB/25-PM and 65-PB/35-CH blends, but had little effect on the 50-PB/50-BS blend. Expanded shale increased the container capacity water content of compost. At the 60% expanded shale content, all landscape mixes

had similar container capacity water contents that were primarily determined by the expanded shale component of the mix.

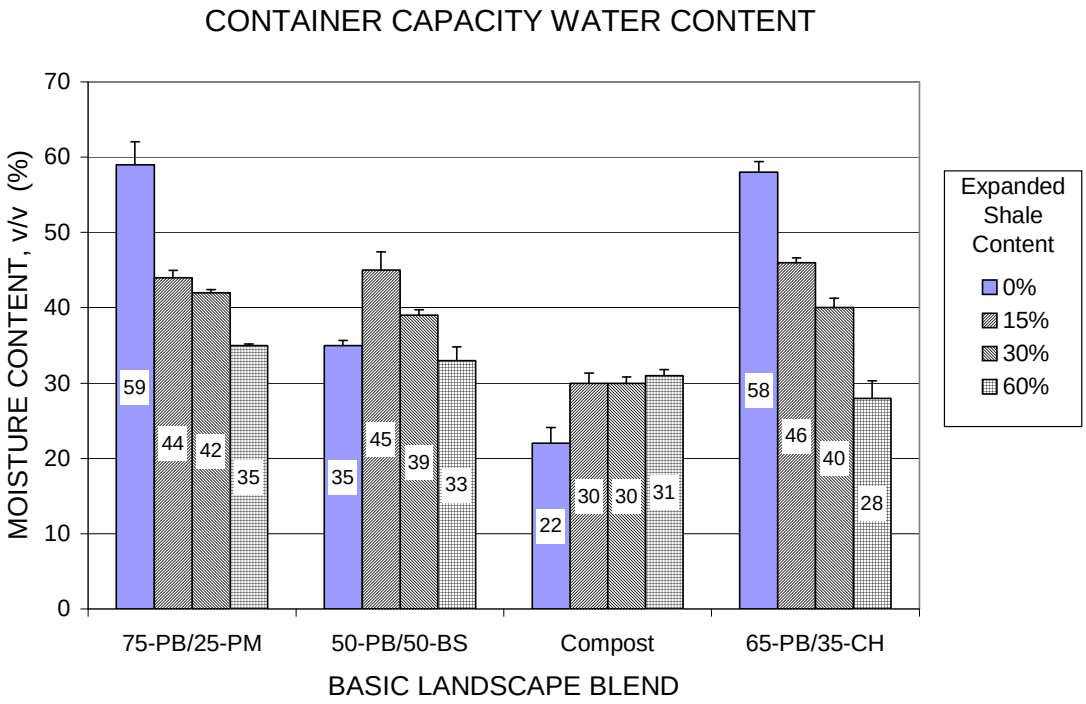

Fig. 3. Effect of TrueGro expanded shale on container capacity water content of various organic landscape mixes.

Plant Growth

Vinca: Vinca is a medium size annual ornamental plant that produces multiple flowers. It is usually propagated through direct seeding. Vinca seeds measure about 1 mm in diameter. Fig. 4 shows the effect of the various landscape mixes on the germination rate of Vinca seeds. Vinca seeds germinated best in the traditional 75-PB/25-PM mix and the compost mix. Expanded shale had little or no effect on Vinca seed germination in these mixes. Vinca seed germination was poorer in the 65-PB/35-CH blend followed by the 50-PB/50-BS blend. However, expanded shale increased Vinca seed germination in the 65-PB/35-CH mix and even more so in the 50-PB/50-BS mix. Poor seed germination in these mixtures was probably due to poor physical contact between the seed and the growing medium, which tended to be somewhat coarse for these two mixes. It is likely that expanded shale improved physical properties in these coarse textured mediums and improved conditions for seed germination.

In terms of plant height and width, Vinca plants grew equally well in all the mixes, except for the 65-PB/35-CH blend (Fig. 5). Vinca growth was so poor in the 65-PB/35-CH blend that no growth data was collected. The plant height and width data suggested that expanded shale had little or no effect on plant growth, but total biomass data (Fig. 6) showed that expanded shale decreased plant growth in the traditional 75-PB/25-PM mix and the 50-PB/50-BS mix, especially at the 60% rate of expanded shale. In the compost mix, the 15 and 30% rates of expanded shale slightly increased Vinca biomass production, but reduced it at the 60% rate. In general, overall Vinca growth was better in the compost mixtures than in the other landscape mixes.

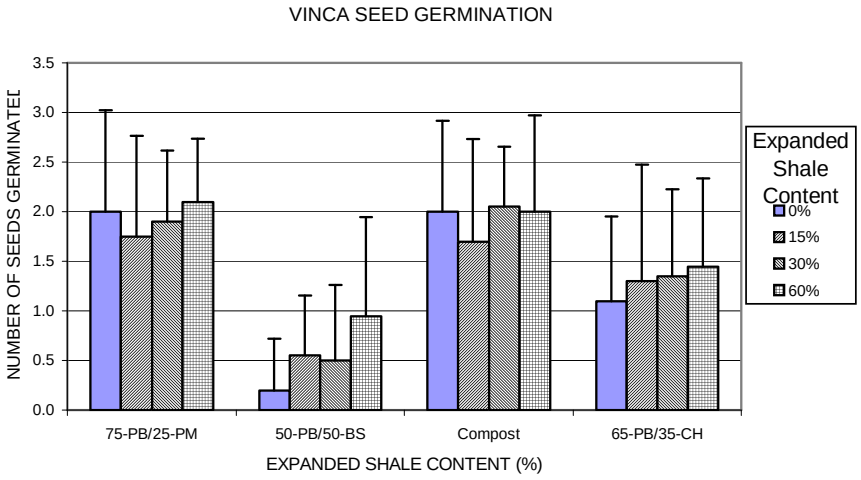

Fig. 4. Effect of expanded shale on germination of Vinca seed in various organic landscape mixes.

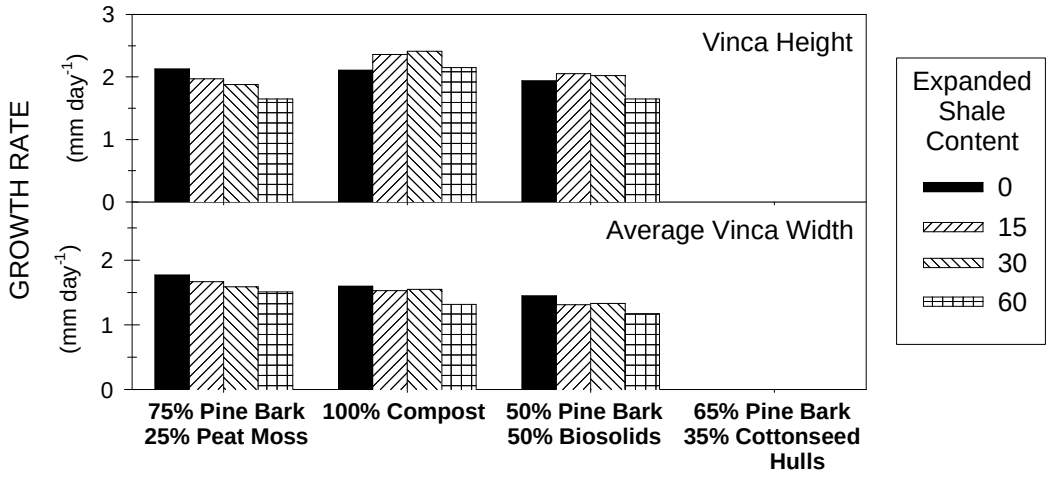

Fig. 5. Effect of TrueGro expanded shale on the rate of Vinca growth as measured by average daily increase in plant height and width during 100 days after planting.

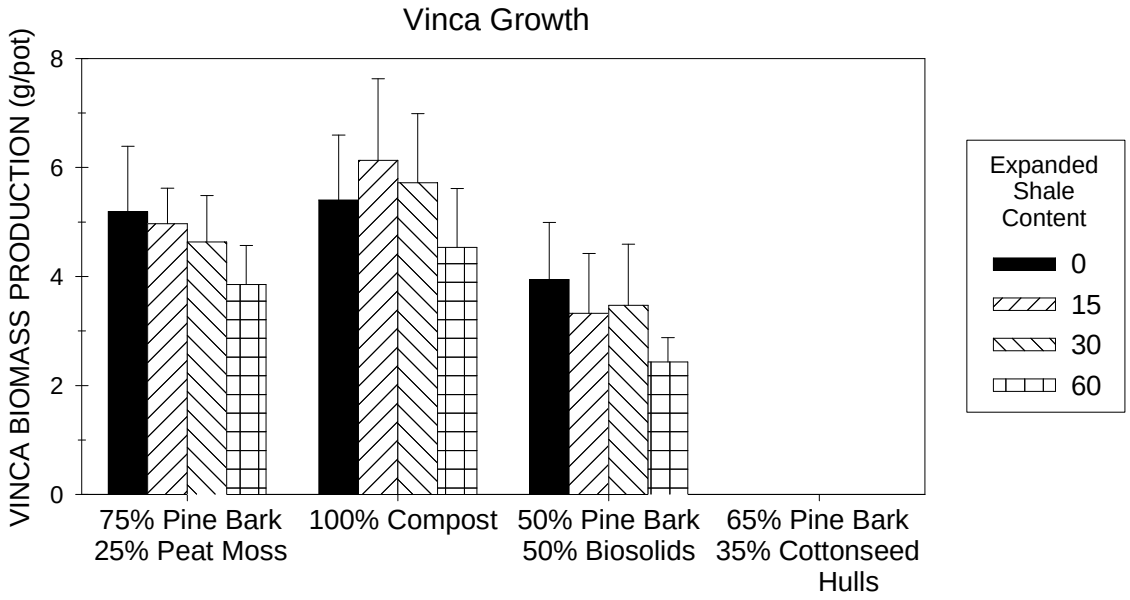

Fig 6. Vinca biomass yield in various organic mixtures containing 0, 15, 30, or 60% TrueGro expanded shale.

Vinca Chlorosis: Chlorosis is a general indication of nutrient deficiency. Chlorosis ratings were taken two weeks before Vinca plants were harvested, which corresponded to a period when fertilizer nutrients applied to the landscape mixes had been depleted by leaching and plant uptake (Table 4). During the last month of growth, Vinca plants relied primarily on the inherent fertility of the landscape mix, which was mostly a reflection of the organic ingredients in the mix. Vinca plants growing in the Pine bark/biosolids mixtures showed no symptoms of choruses for any of the expanded shale rates. Plants growing in the compost showed some choruses, which increased with rate of expanded shale. The pine bark/peat moss mixtures showed moderate choruses with low rates of expanded shale and the choruses worsened with increasing rates of expanded shale. Lower nutrient available with increasing rates of expanded shale can be attributed to nutrient dilution. Expanded shale has no inherent fertility. As the amount of expanded shale in the mixture increases, the amount of nutrient-supplying organic ingredients is decreased. Therefore, the landscape mix that contained 60% expanded shale had much lower available nutrients than the same landscape mix without expanded shale.

Table 4. Effect of expanded shale on chlorosis ratings for three landscape mixes. Rating range from 0 (no choruses) to 5 (extreme choruses).

Expanded Shale Content	Basic Landscape Blend		
	75-PB / 25-PM	50-PB / 50-BS	Compost
(%)	(0 = no choruses, 5 = extreme choruses)		
0	1.80	0	0.25
15	1.15	0	0.35
30	2.15	0	0.35
60	4.05	0	0.75

Verbena: In the landscape mixes without expanded shale, there was no difference between Verbena biomass production in the 50-PB/50-BS and the traditional 75-PB/25-PM landscape mixes for the first harvest. Biomass production in the compost mix was significantly lower (Fig. 7). A similar trend was observed for the second harvest, although the total yields were lower. The first harvest of the 65-PB/35-CH mix was very low compared to the other three organic blends, but the differences were much smaller for the second harvest. In fact, Verbena growth in the 65-PB/35-CH blend appeared to be improving at the time the second harvest was collected. It is likely that the cottonseed hulls needed to be aged (i.e., partially decomposed) before being used in the landscape mix.

TrueGro expanded shale had mixed effects on the landscape mixes. Verbena growth in the 50-PB/50-BS mix, the traditional 75-PB/25-PM mix, and the 65-PB/35-CH mix was significantly reduced by the addition of expanded shale for both the first and second harvests. However, Verbena growth in the compost mix was significantly increased by the addition of up to 30% TrueGro expanded shale for the first harvest, but had little effect on verbena growth for the second harvest. It is likely that expanded shale improved drainage and aeration in the compost mix, which originally lacked optimal levels of these properties. However, the other three landscape mixes were already sufficiently porous, so the addition of expanded shale caused excessive drainage and reduced their ability to retain moisture.

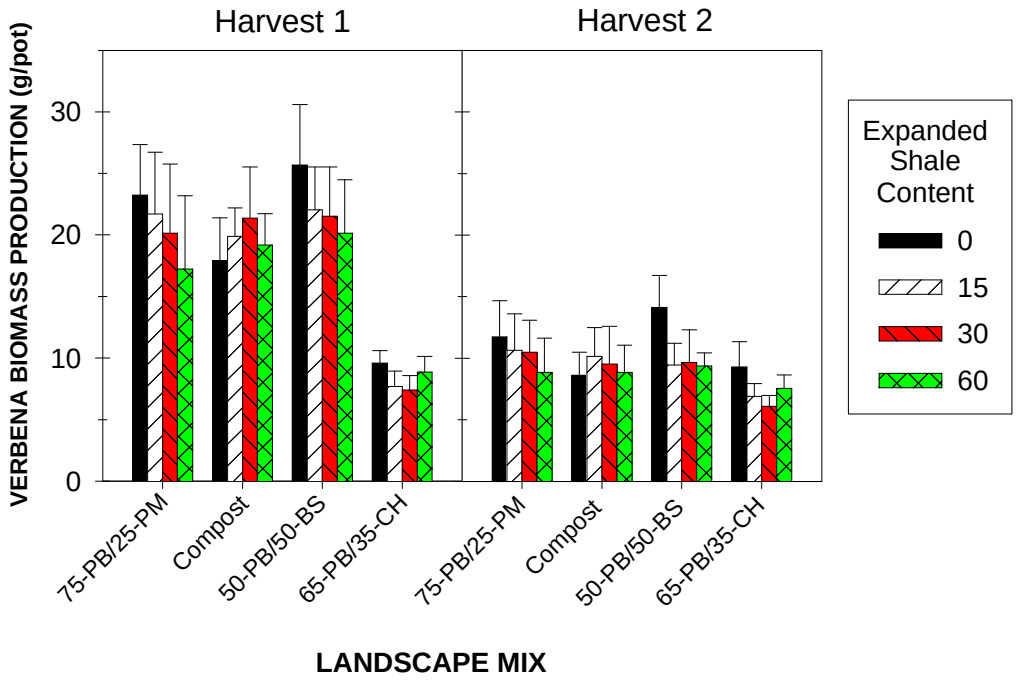

Fig 7. Verbena biomass production from two successive harvests of aboveground foliage for various organic landscape mixes combined with 0, 15, 30, and 60% TrueGro expanded shale.

Shantung Maple: Maples grew fastest in the pine bark + biosolids mixture (Fig. 8), probably due to the high concentration of available nutrients in fresh biosolids, especially nitrogen (Tables 1 and 2). Compost performed nearly as well as the traditional pine bark + peat moss mixture. Maples grew poorly in the pine bark + cottonseed hull mixture, possibly due nitrogen immobilization.

A 60% addition of expanded shale to compost and a 30 to 60% addition to the pine bark + cottonseed hull mixture had positive effects on maple growth. In the 50-PB/50-PM mixture and the traditional 75-PB/25-PM mixture, maple growth was not affected by the addition of 15 and 30% expanded shale, but was decreased by the addition of 60% expanded shale.

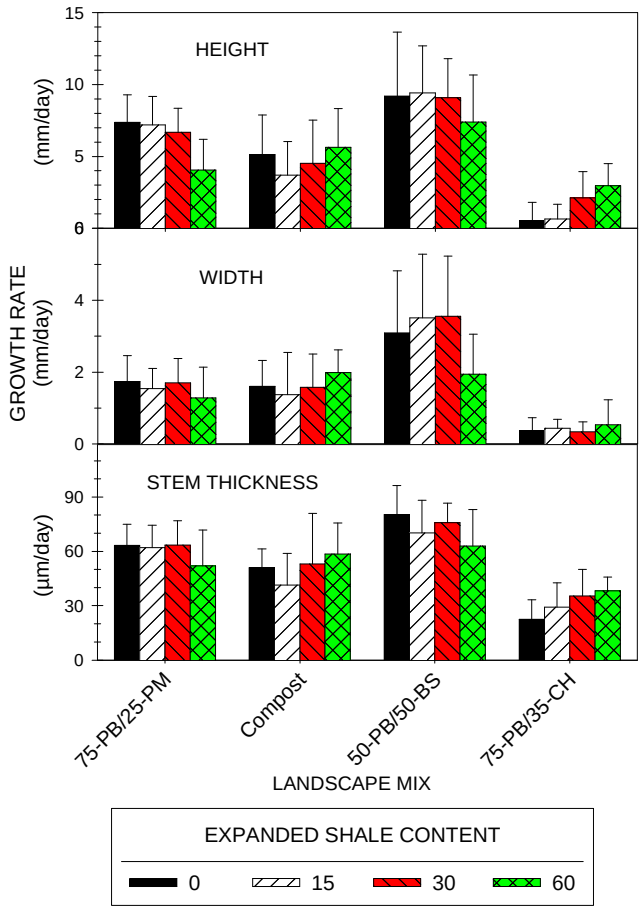

Fig. 8. Growth rate of Shantung maple in organic landscape mixes containing 0, 15, 30, and 60% TrueGro expanded shale.

Vinca Tissue Analysis

Major nutrients: Vinca tissue was analyzed for total major nutrients (N, P, K, Mg, Ca) to determine the effect of landscape mixes on plant nutrition (Table 5). There is no data for the 65-PB/35-CH mixes because Vinca plants failed to grow in these cottonseed hull mixtures. Fertilizer was added once to all pots at the start of the study, so later Vinca growth was influenced mostly by the inherent fertility of the landscape blends. Nitrogen concentrations were highest in the 50-PB/50-BS mixes due to large amounts of both total N and NO_3-N in the biosolids (Tables 1 and 2). There were no differences in the concentrations of nitrogen in Vinca plants grown in the other mixes. There was a slight trend towards reduced nitrogen uptake as the expanded shale content was increased to 60%, but the effect was very small and probably due to a dilution effect. That is, expanded shale displaced organic ingredients in the blend and reduced the amount of available nitrogen.

Phosphorus uptake by Vinca was highest for the 75-PB/25-PM mixes, followed closely by the 100-Compost mixes and finally by the 50-PB/50-BS mixes. Expanded shale tended to decrease phosphorus uptake by Vinca. This is due to the ability of expanded shale to adsorb phosphorus and remove it from solution. For the 50-PB/50-BS mixes, it appears that phosphorus uptake was slightly increased by the presence of expanded shale. Biosolids contain a large amount of soluble phosphorus that is susceptible to leaching. It is possible that the expanded shale adsorbed some of this soluble phosphorus, which protected it from leaching and made it available to Vinca plants through desorption after fertilizer phosphorus had been depleted.

Potassium concentratins were nearly identical for Vinca grown in the 75-PB/25-PM and 100-Compost mixtures, but was significantly lower for Vinca grown in the 50-PB/50-PM mix. Biosolids tend to be low in potassium because wastewater treatment does not remove significant K from the wastewater stream. Expanded shale had no effect on K uptake by Vinca. This is not surprising because K^+ chemistry is controlled by cation exchange reactions and expanded shale has no significant cation exchange capacity.

Vinca Mg concentrations were similar for plants grown in all three basic blends. There was a trend for expanded shale to increase Mg concentrations. Expanded shale contains a significant amount of soluble Mg, which plants could utilize – especially when Mg levels are below optimal levels.

Vinca Ca concentrations were mostly affected by the organic ingredients in each landscape mix. Calcium uptake was greatest in Vinca grown in the 50-PB/50-BS mixes, followed by the 100-Compost mixes and then the 75-PB/25-PM mixes. The biosolids used in this study were treated with $Ca(OH)_2$ in order to raise pH and kill pathogens. Calcium hydroxide is a solubel source of Ca, thus the 50-PB/50-BS blends contained more plant available Ca than the other blends. Expanded shale also contains a significant amount of soluble Ca. Expanded shale significantly increased Vinca Ca concentrations in the 75-PB/25-PM mixes where plant available Ca levels were lower. This suggest that expanded shale can be a significant source of Ca in growing mediums that contain less than optimal levels of plant available Ca.

Table 5. Effect of organic ingredients and expanded shale content on the concentration of major nutrients in Vinca foliage.

Base Blend	Exp. Shale Content	N†	P	K	Mg	Ca
	(%)	(mg/kg)	(g/kg)	(mg/kg)	(g/kg)	
75-PB/25-PM	0	27.3 c	3.31 a	29.1 ab	2.02 de	1.4 g
75-PB/25-PM	15	27.3 c	2.86 b	29.2 ab	2.72 b	2.2 fg
75-PB/25-PM	30	25.9 cd	2.66 bc	28.6 ab	3.08 b	3.3 f
75-PB/25-PM	60	25.4 cd	2.19 de	29.0 ab	4.32 a	5.4 e
50-PB/50-BS	0	31.4 ab	1.66 f	24.3 d	2.68 bc	14.2 a
50-PB/50-BS	15	32.6 a	1.74 f	25.4 cd	2.60 bc	15.7 a
50-PB/50-BS	30	30.4 ab	1.89 ef	23.7 d	2.90 b	14.1 a
50-PB/50-BS	60	30.3 b	1.97 def	23.5 d	3.06 b	12.1 b
100-Compost	0	26.4 cd	2.34 cd	29.7 a	1.89 e	8.9 cd
100-Compost	15	26.0 cd	2.18 de	30.0 a	2.10 cde	7.9 d
100-Compost	30	26.0 cd	2.58 bc	28.3 ab	2.03 de	8.7 cd
100-Compost	60	24.4 d	2.19 de	26.9 bc	2.48 cde	10.2 c

† For each nutrient, values followed by the same letter are not statistically significant (p=0.05).

Trace metals: Vinca plants were analyzed for trace metal contents to assess both plant nutritional aspects as well as environmental concerns (Table 6). Copper and Zn are both essential trace elements that plant require for optimal growth and development. Both these elements were present in sufficient concentrations in Vinca plants grown in all landscape mixes. The were only small differences in Vinca Cu concentrations among the three basic organic blends. There was a trend towards reduced Cu uptake with increasing rates of expanded shale, especially in the 75-PB/25-PM amd 100-Compost mixes where available Cu was slightly lower than in the 50-PB/50-PM mixes. Vinc Zn concentrations were highest for the 50-PB/50-PM mixes followed by the 75-PB/25-PM mixes, and then the 100-Compost mixes. There was a significant reduction in Vinca Zn concentrations with increasing rates of expanded shale for all three basic organic blends. The effect was most pronounced for the 75-PB/25-PM mixes. Both Cu and Zn solubility are inversely related to pH. Adding expanded shale to the basic organic blends increased their pH values and reduced the solubility of Cu and Zn. Thus, there was less plant available Zn in the mixes that contained large amounts of expanded shale. Fortunately, the levels of plant available Zn did not fall below levels that are sufficient for plant growth.

Landscape mixes are typically used where ornamental plants are grown, but they might also be used to grow food crops, such as vegetables. Therefore, plant uptake of heavy metals is a concern, especially when alternative organic ingredients such as biosolids and compost are included in the mix. Concentrations of chromium, nickel and lead in Vinca plants were generally similar among the three basic organic blends. Heavy metal solubility is decreased with increasing pH, so it was logical to expect a decrease in uptake of Cr, Ni, and Pb with increasing rates of expanded shale. The fact that no decrease was observed suggests that levels of these metals were initially quite low in all the landscape mixes. In fact, plant concentrations of these metals were near to or below the analytical detection limit.

Table 6. Effect of organic ingredients and expanded shale content on the concentration of heavy metals in Vinca foliage.

Base Blend	Expanded Shale Content	Cr†	Cu	Ni	Pb	Zn
	(%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
75-PB/25-PM	0	5.4 bc	8.8 b	3.1 b	6.3 c	47.9 bc
75-PB/25-PM	15	7.8 ab	8.7 bc	3.7 b	10.5 ab	37.0 de
75-PB/25-PM	30	5.7 abc	6.7 cd	3.1 b	6.9 bc	31.3 fg
75-PB/25-PM	60	5.0 c	6.3 d	4.0 b	8.7 abc	19.0 h
50-PB/50-BS	0	5.1 c	9.7 ab	4.4 b	10.3 abc	53.9 a
50-PB/50-BS	15	6.3 abc	8.8 b	4.2 b	10.1 abc	48.4 b
50-PB/50-BS	30	7.1 abc	9.0 b	6.3 a	7.5 bc	44.2 c
50-PB/50-BS	60	8.0 a	11.4 a	4.3 b	12.0 a	36.6 de
100-Compost	0	6.0 abc	9.2 b	3.5 b	9.8 abc	38.7 d
100-Compost	15	4.7 c	9.0 b	3.5 b	8.7 abc	35.1 def
100-Compost	30	6.4 abc	8.6 bc	3.8 b	9.5 abc	33.5 ef
100-Compost	60	5.6 abc	8.4 bc	4.1 b	10.0 abc	28.1 g

† For each metal, values followed by the same letter are not statistically significant (p=0.05).

CONCLUSIONS

Expanded shale has positive short-term effects on plant growth when added to landscape mixes that lack optimum drainage and aeration. This is true of landscape mixes that contain decomposed organic materials usch as municipal yard waste compost. Other organic landscape mixes perform better as plant growing mediums without the addition of expanded shale. These mixes typically contain course organic materials such as pine bark. Combining expanded shale with locally-obtainable organic ingredients, such as biosolids or municipal yard waste compost, can create landscape mixes that perform as well or better than traditional pine bark + peat moss based mixtures. Continued research is needed to determine the long-term effects of including expanded shale in non-traditional landscape mixtures. Landscape mixes are typically added to soil and not used to directly grow plants as was done in this study. Landscape mixes that contain expanded shale may have long-term beneficial effects that cannot be expressed during a short-term greenhouse potting study.